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## SUBSTITUTE SPECIFICATION

**METHOD FOR CONTROLLING THE EMISSION POWER OF A  
TRANSCIVER IN COMMUNICATION WITH ANOTHER TRANSCIVER**

**[0001]** This nonprovisional application claims priority under 35 U.S.C. § 119(a) on Patent Application No. 99401272.2 filed in the United Kingdom on May 27, 1999, which is herein incorporated by reference.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

**[0002]** The present invention relates to a method for use in controlling the emission power of a transceiver which is in communication with another transceiver, for use for example in a wireless communication system.

2. Description of the Background Art

**[0003]** Reference will now be made to Fig. 1 of the accompanying drawings which shows a transceiver 10 in communication with another transceiver 20 via a wireless communication system. Transceiver 10 is for example located in a base station and transceiver 20 in a mobile station. Data are exchanged between the transceiver 10 and the transceiver 20 via a wireless interface, a so-called radio channel. In Fig. 1, the transceiver 20 receives from the transceiver 10 a radio signal referenced as RC and sends to the transceiver 10 a radio signal with a power referenced as P. The same is for transceiver 10.

**[0004]** The characteristics of radio channels (for example: phase and amplitude) change continuously, due to variations in the geographical environment between a mobile station and a base station. These variations can be separated into free space propagation losses, slow fading and fast fading losses. Free space propagation losses depend on the path length between the transmitter and the receiver and can be modelled by a  $d^{-n}$  law where  $n$  is a number between 2 and 4 and  $d$  is the path length. Slow fading losses are due to shadowing occurring when obstacles, such as buildings, trees, etc., are

interposed between the transmitter and the receiver. Slow fading losses are known to generate variations in channel power for movements that are in the order of 10 times the wavelength of the radio signal. They can be modelled by a log normal law the standard deviation  $\sigma$  of which ranges between 4 and 12 dB depending on the kind of environment. Finally, fast fading losses are due to multipath effect in which a signal follows different paths and the resulting received signals recombine at the receiver entrance with different delays, amplitudes and phases. They can be modelled by a Rayleigh distribution. Movements that are in the order of 1/100 of the wavelength of the radio signal are sufficient to generate fast fading.

**[0005]** Most telecommunication systems use power control methods to limit interference and power consumption. Power control methods aim to command an emission power of both transceivers as close as possible to the minimum needed for a defined quality of transmission.

**[0006]** Such a method includes, carrying out in an evaluating unit 200 of a transceiver (here the transceiver 20), the steps of measuring the received power of the radio signal RC (or its amplitude) and, on basis of the result of this measurement, of evaluating a power control command  $PC$ . The power control command  $PC$  is used to command a transmission unit 210 so that it transmits signals with a power  $P$  corresponding to the command  $PC$ .

**[0007]** Note that the transceiver 10 comprises also such an evaluating unit and a transmission unit.

**[0008]** Due to the time duration (referenced as  $t_d$  in the following description) between the moment of the input amplitude measurement (made in the evaluating unit 200) and the moment of the use of the control command signal  $PC$  to command the emission power  $P$  (made in the transmission unit 210), the power control methods are based on a measurement and an evaluation which are made during reception and which are used to determine the power to be transmitted during the next emission.

**[0009]** The value of the time duration  $t_d$  is imposed by the system for given periods and thus is known by the considered transceiver.

**[0010]** The emission power  $P$  is applied with a certain delay  $t_d$  after the

measurement has been made by the evaluating unit 200; hence the channel features can have significantly changed between the evaluation and the application of the *PC* command. The power control command *PC* then wrongly compensates the channel variations, particularly in the case of fast fading losses, where the stronger the fading is, the quicker it disappears.

### SUMMARY OF THE INVENTION

**[0011]** It is therefore an object of the present invention to overcome the above-mentioned problem and then to propose a method for adaptive power control, which can be used in communication systems wherein the power control delay is longer than the time needed for significant variations in channel features to occur.

**[0012]** To this end, a method for controlling the emission power of a transceiver in communication with another transceiver of a communication system according to the present invention includes the steps of evaluating the fast fading duration and of deducing the power control command from the fast fading duration on basis of the amplitude or the power measurement made by the receiver.

**[0013]** According to another feature of the invention, the method includes, for deducing the power control command, the step of comparing the evaluated fast fading duration with the time duration between the amplitude or the power measurement and the emission power setting, and according to the result of the comparison, in determining said the power control command.

**[0014]** According to another feature of the invention, the method includes the step of setting the control command signal *PC* at the inverse of the measured amplitude  $1/L_m$  if the fast fading duration  $t_f$  is higher than the time duration  $t_d$  between the amplitude or power measurement and the emission power setting and at the inverse of the short-term average of the measured amplitude  $1/L_{av}$  if it is equal to or lower than said time duration

$$i. \quad \begin{array}{l} 1/L_m \text{ if } t_f > t_d \\ 1/L_{av} \text{ if } t_f \leq t_d \end{array}$$

**[0015]** Further scope of applicability of the present invention will become

apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus, are not limitive of the present invention, and wherein:

**[0017]** Fig. 1 is a schematic diagram illustrating a communication system provided with a power control system;

**[0018]** Fig. 2 is a block schematic diagram of an evaluating unit of a transceiver in a communication system provided for carrying a method according to the inventions; and

**[0019]** Fig. 3 is a graphic illustrating the received amplitude with time for use in explaining the method according the invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0020]** The method of the invention is applied to a communication system such as the system represented in Fig. 1 and is carried out in the evaluating unit of each transceiver 10, 20 of the communication system. Only, the evaluating unit 200 of the transceiver 20 is now considered.

**[0021]** The evaluating unit 200 depicted in more detail in Fig. 2 has a measurement unit 21 for measuring at predetermined times  $t$  the amplitude  $L_m$  of the received signal  $RC$ , a averaging unit 22 for determining the short-term average  $L_{av}$  of the measured amplitude  $L_m$ , an estimation unit 23 for estimating the fading duration  $t_f$  and a control unit 24 for determining the power control command signal  $PC$  which is provided for use by a transmission unit 210 to set the emission power  $P$  at the value given by the  $PC$  command.

**[0022]** Fig. 3 shows the variations with time of the received amplitude  $L$  at

the receiver 20 input. Downward arrows indicate measurement times made by the evaluating unit 200 and upward arrows indicate the emission times made by the transmission unit 210. At measurement times, the received amplitude is the measured amplitude and is noted  $L_m$ . The dotted line represents the short-term average of the measured amplitude  $L_m$  that is then noted as  $L_{av}$ . The received amplitude  $L$  is representative of the free space fading, of the shadowing fading and of the fast fading. The short time average amplitude  $L_{av}$  is representative of only the free space fading and the shadowing fading.

**[0023]** Note that the short-term amplitude  $L_{av}$  is defined as being the average of the measured amplitude  $L_m$  over time periods corresponding to the variation time of the slow fading essentially due to shadowing.

**[0024]** The fading duration  $t_f$  is defined as being the average time for which the received amplitude  $L$  will stay below the measured amplitude  $L_m$  if said measured amplitude  $L_m$  is lower than the short-term average amplitude  $L_{av}$  or above the measured amplitude  $L_m$  if said measured amplitude  $L_m$  is higher than the short-term average amplitude  $L_{av}$ .

**[0025]** In order to optimise the confidence level of the power control, the method according to the invention determines the power control command signal regarding the estimated fading duration  $t_f$  derived from the fading depth  $L/L_{av}$ . In other words, the power control command value  $PC(t_d)$  is equal to the inverse of measured amplitude if the fading duration  $t_f$  is longer than the delay  $t_d$  between the moment of the amplitude measure made by the evaluating unit 200 and the application of the power control command  $PC(t_d)$  to the transmission unit 210 and is equal to the inverse of the average amplitude  $L_{av}$  if it is shorter:

$$i. \quad \begin{cases} 1/L_m & \text{if } t_f > t_d \\ 1/L_{av} & \text{if } t_f \leq t_d \end{cases}$$

**[0026]** Note that the power control command value  $PC(t_d)$  is the value which will be used by the transceiver 20 at the present time +  $t_d$  to set the emission power  $P$  at the evaluated value  $PC(t_d)$ .

**[0027]** In Fig. 3, at time  $t_1$ , the fading time  $t_f$  is shorter than the time duration  $t_d$ . Hence, the power control command  $PC(t_d)$  is the inverse of the short

term average amplitude  $1/L_{av}$ . It is the same for the time  $t_3$ . At time  $t_2$ , the fading time  $t_f$  is higher than the time duration  $t_d$ . Hence the power control command  $PC(t_d)$  is the inverse of the measured amplitude  $1/L_m$ . It is the same for time  $t_4$ .

**[0028]** Note that the fading duration is too short to impact upon the emission for cases  $t_1$  and  $t_3$  but it is long enough to do so for cases  $t_2$  and  $t_4$ .

**[0029]** The method of the invention give an adaptive amplitude correction able to balance fast fading as well as shadowing and free space losses, since the short-term amplitude average  $L_{av}$  correct shadowing and free space channel variations.

**[0030]** Note that the estimation unit 23 needs the value of the speed  $v$  of the transceiver 20 relative to the transceiver 10 to evaluate the fading duration  $t_f$ . A dedicated unit (not shown) can determine or evaluate and deliver this value.

**[0031]** From a publication of Gans in IEEE Trans. Veh. Technol., Vol. VT21, February 1972, pp.27-38, the fast fading duration can be estimated in the following way:

$$t_f = \begin{cases} (a) & \text{if } \bar{L} < 1 \\ (b) & \text{if } \bar{L} > 1 \end{cases} \quad \frac{\lambda}{\sqrt{2\pi L} v} [e^{\bar{L}} - 1]$$

where  $\bar{L}$  is the measured amplitude  $L_m$  at a measurement time normalised by the short-term average amplitude  $L_{av}$  ( $\bar{L} = L_m/L_{av}$ ),  $v$  and  $\lambda$  are respectively the speed of one transceiver 10 relative to the other 20 and the wavelength of the carrier used by the communication system.

**[0032]** The power control command  $PC(t_d)$  can be now given by the following scheme:

$$a. \quad PC(t_d) = \begin{cases} 1/L_m & \left\{ \begin{array}{l} \text{if } \bar{L} < 1 \text{ and } t_d < \frac{\lambda}{\sqrt{2\pi} \bar{L} v} [e^{(\bar{L}^2)} - 1] \\ \text{if } \bar{L} \geq 1 \text{ and } t_d < \frac{\lambda}{\sqrt{2\pi} \bar{L} v} \end{array} \right. \\ 1/L_{av} & \left\{ \begin{array}{l} \text{if } \bar{L} < 1 \text{ and } t_d \geq \frac{\lambda}{\sqrt{2\pi} \bar{L} v} [e^{(\bar{L}^2)} - 1] \\ \text{if } \bar{L} \geq 1 \text{ and } t_d \geq \frac{\lambda}{\sqrt{2\pi} \bar{L} v} \end{array} \right. \end{cases}$$

where  $PC(t_d)$  is the power control command which will be used at the present time (assumed to be zero) +  $t_d$ ,  $L$  is the received amplitude,  $L_{av}$  is the short-term average of the measured amplitude,  $t_d$  is the time delay between the moment of the measurement of the received amplitude  $L_m$  and the use of the  $PC$  command and  $\bar{L} = \frac{L_m}{L_{av}}$  is the normalised received amplitude.

[0033] A simplified equation can easily be derived:

$$PC(t_d) = \begin{cases} 1/L_m & \text{if } t_d < \frac{\lambda * \min\left(\bar{L}, \frac{1}{L}\right)}{\sqrt{2\pi} v} \\ 1/L_{av} & \text{if } t_d \geq \frac{\lambda * \min\left(\bar{L}, \frac{1}{L}\right)}{\sqrt{2\pi} v} \end{cases}$$

[0034] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are to be included within the scope of the following claims.

What is claimed is: